INFRARED RADIATION CALCULATOR

AND USER GUIDE

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INSTRUCTIONS FOR USING THE INFRARED RADIATION CALCULATOR

Conversions of temperatures among Celsius, Kelvin, Fahrenheit, and Rankine scales

Use A, B, K, and L scales. Set the temperature at the index mark on one scale and read corresponding temperature on another. Note the extra index at the left on the M scale to indicate the wavenumber (cm^{-1}) corresponding to λ_{max}, the wavelength for the maximum of the blackbody curve. This can be used in calculating the energy of a photon, $E_{photon} = h\nu$.

Total blackbody radiant exitance, M

Set the temperature of the blackbody source on a temperature scale and read on the D scale ($W\ cm^{-2}$). An emissivity scale (C scale) associated with the D scale permits direct calculation for graybodies.

Spectral blackbody radiant exitance at peak of blackbody curve, $M_{\lambda\ max}$

Set the desired temperature on a temperature scale and read directly from the E scale.

Ratio of M_λ at any wavelength, λ, to that at λ_{max}, $M_\lambda/M_{\lambda\ max}$

Set the desired temperature on a temperature scale; then read $M_\lambda/M_{\lambda\ max}$ from the F scale opposite the desired λ on the G scale. Find the M_λ for the selected wavelength as follows: On the E scale, find the $M_{\lambda\ max}$ for the selected temperature. Then multiply this value by the value of $M_\lambda/M_{\lambda\ max}$ read from the F scale as noted above.

Blackbody radiation in a spectral interval

Set the temperature scale to the appropriate temperature. Then on the J scale ($M_{0-\lambda}/M_{0-\infty}$), read the percentage radiation that lies at wavelengths shorter than λ_2, the longer wavelength interval boundary. Repeat for λ_1, the shorter wavelength interval boundary. Subtract to obtain percentage of total radiation in the spectral interval.

To obtain $M_{\Delta\lambda}$, total $W\ cm^{-2}$ for the spectral interval, take this calculated percentage of M, total blackbody radiant exitance as read from D scale. For graybodies, read from D scale for emissivity from C scale.

Irradiance from a 1 cm^2 blackbody on a surface normal to incoming direction at a given range

Set blackbody temperature. Read irradiance ($W\ cm^{-2}$) on U scale for range in cm or on V scale for range in nautical miles.

Conversion among units of total blackbody radiant exitance

Use D ($W\ cm^{-2}$), O ($W\ in^{-2}$), and P ($Btu\ ft^{-2}\ hr^{-1}$) scales. Line up selected value with emissivity of 1.0 on one scale, read converted values at emissivity of 1.0 on other scales.

Transmission coefficient of atmosphere

Use G scale as abscissa for H scale.

Number of photons $sec^{-1}\ cm^{-2}$ from a blackbody

Set temperature on A, B, K, or L scale. Read result at index mark on R scale. Also read photon energy at λ_{max} at index mark on S scale.

Other combinations of the above calculations, as well as useful equations and constants, can also be obtained from the infrared radiation calculator.

Note

The calculator is suitable for approximate calculations. Inaccuracies may occur when both faces of the calculator are used in one calculation, as the two faces of the slide can not be perfectly aligned during printing. It is therefore preferable to set the selected temperature on the face to be used in the calculation. If both faces are used in a single calculation, adjust as follows: Set the temperature in Kelvin at 900 K (B scale) and read the Fahrenheit temperature (K scale). The horizontal distance between your reading and 1160° F is constant in length for all scales.

EXAMPLE OF INFRARED RADIATION CALCULATOR USE

Assume a surface with temperature of 900 K. Set the calculator to 900 K (B scale). This corresponds to a temperature of 627° C (A scale), 1160° Fahrenheit (K scale), and 1620° Rankine (L scale).

At this temperature, the total radiant exitance of a blackbody is 3.7 W cm^{-2} (D scale). This value corresponds to 24.0 W in^{-2} (O Scale) or 11.8 x 10^4 BTU ft^{-2} hr^{-1} (P scale). For an oxidized iron surface (emissivity 0.7), the radiant exitance would be 2.55 W cm^{-2} (D scale).

For the same temperature, a blackbody reaches its peak value of spectral blackbody radiant exitance, $M_{\lambda max}$, at a wavenumber of 3100 waves cm^{-1} (M scale) or a wavelength of 3.22 micrometers (I scale). The value of $M_{\lambda max}$ is 0.75 W cm^{-2} $micrometer^{-1}$ (E scale).

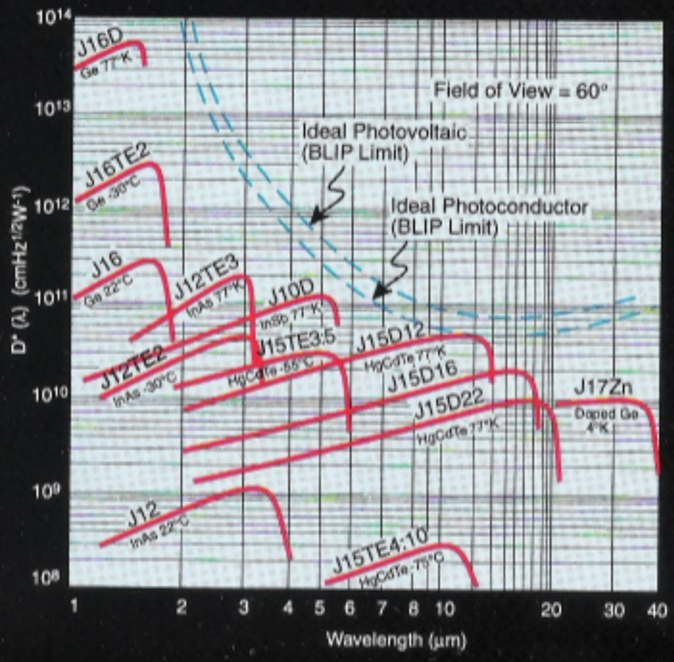
At 5.0 micrometers (G scale), the ratio $M_{\lambda}/M_{\lambda max}$ (F scale) is 0.66. Therefore, the spectral blackbody exitance, M_{λ}, at 5.0 micrometers is 0.66 x 0.75 or 0.50 W cm^{-2} $micrometer^{-1}$

What is the total radiant exitance of a 900 K blackbody falling in the 3.0 to 5.0 micrometer range? Using the I and J scales, 57% of the total radiant exitance is at wavelengths shorter that 5.0 micrometers, 21% at wavelengths shorter than 3.0 micrometers. The total radiant exitance in the band is therefore (57% – 21%) or 36% of 3.7 W cm^{-2} (from D scale), or 1.33 W cm^{-2}

The irradiance from a 1 cm^2 blackbody on a surface normal to the incoming direction at a range of 10^3 cm (10 m) (T scale) is 1.02 x 10^{-6} W cm^{-2} (U scale). In the 3.0 to 5.0 micrometer band, it is 36% of this value or 0.367 x 10^{-6} W cm^{-2}.

The number of photons sec^{-1} cm^{-2} from a blackbody at the index temperature is 1.08 x 10^{20} (R scale). The photon energy at λ_{max} is 0.382 electron volt (S scale).

Typical Detectivity and Wavelength Range for **EG&G JUDSON** Infrared Detectors



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Infrared Radiation Calculator

Use this slide rule to aid in the design and analysis of radiation measuring and sensing systems using EG&G Judson Infrared Detectors.

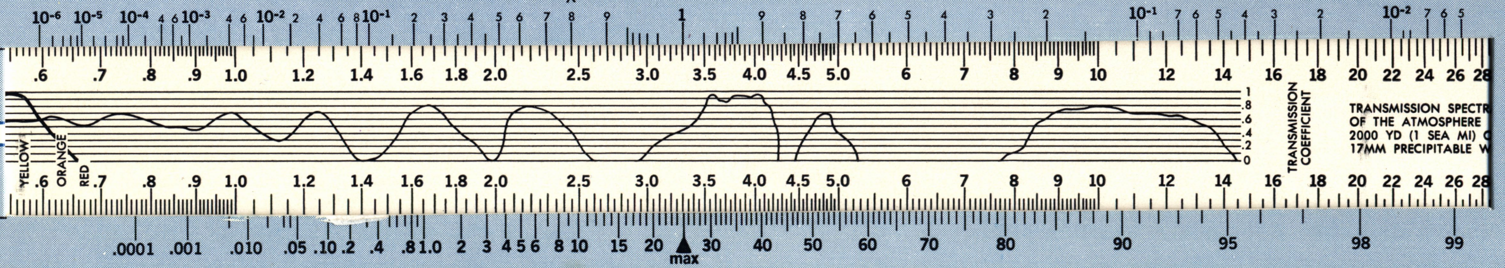
A	TEMP. (°C) CENTIGRADE	
B	TEMP. (K) KELVIN	°C + 273
C	EMISSIVITY	ε
D	WATTS/SQ. CM	M
E	WATTS/SQ. CM/MICROMETERS Δλ AT MAXIMUM	M_λ max.

Infrared Detectors from EG&G JUDSON

- J16 Series Ge - 0.8 to 1.8 µm
- J12 Series InAs - 1 to 3.5 µm
- J10 Series InSb - 1 to 5 µm
- J15TE Series HgCdTe - 3 to 5 µm
- J15TE Series HgCdTe - 8 to 10 µm
- J15D Series HgCdTe - 2 to 24 µm
- J17 Series Doped Ge - 2 to 42 µm

FACTOR OF ENERGY AT MAXIMUM M_λ MAX. AT CORRESPONDING WAVELENGTH FOR A BLACK BODY AT TEMPERATURE (T).

F	$\frac{M_\lambda}{M_\lambda \text{ max.}}$
G	λ WAVELENGTH MICROMETERS
H	
I	λ WAVELENGTH MICROMETERS
J	$\frac{M_0 - \lambda}{M_0 - \infty}$



PERCENTAGE INCREMENT OF ENERGY FALLING BELOW ANY WAVELENGTH FOR A BLACK BODY AT TEMPERATURE (T).

EG&G JUDSON

Infrared Radiation Calculator

PLANCK'S EQUATION:

$$M_\lambda = C_1\lambda^{-5}(e^{C_2/\lambda T}-1)^{-1}$$

WIEN'S DISPLACEMENT LAW:

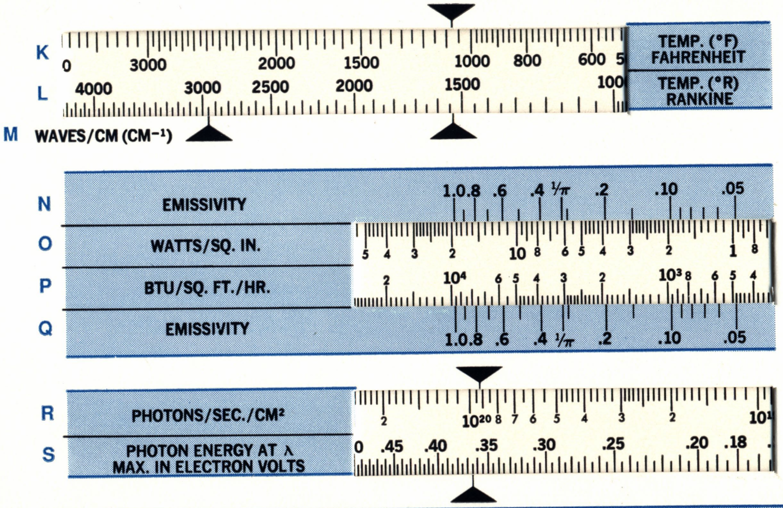
$$\lambda_m = \frac{\alpha}{T}$$

STEFAN-BOLTZMANN LAW:

$$M = \epsilon\sigma T^4$$

STEFAN-BOLTZMANN CONSTANT (σ):

- 5.6697 x 10^{-5} ergs cm^{-2} K^{-4} sec^{-1}
- 5.6697 x 10^{-12} watts cm^{-2} K^{-4}
- 1.355 x 10^{-12} cal cm^{-2} K^{-4} sec^{-1}
- 3.658 x 10^{-11} watts in^{-2} K^{-4}
- 1.798 x 10^{-8} Btu ft^{-2} K^{-4} hr^{-1}
- 5.268 x 10^{-12} Kwh ft^{-2} K^{-4} hr^{-1}
- 4.530 x 10^{-9} Kcal ft^{-2} K^{-4} hr^{-1}



SYMBOLS AND PHYSICAL CONSTANTS

M_λ = SPECTRAL RADIANT EXITANCE Watt-cm^{-2} $micrometers^{-1}$

M = TOTAL RADIANT EXITANCE

T = ABSOLUTE TEMPERATURE OF RADIATING BODY (K)

T_0 = ABSOLUTE TEMPERATURE OF SURROUNDINGS (K)

λ = WAVELENGTH IN CENTIMETERS OR MICROMETERS

λ_m = WAVELENGTH IN MICROMETERS OF MAXIMA OF BLACK BODY CURVE

α = CONSTANT FOR BLACK BODY = 2897.9 μm-K

$C_1 = 2\pi c^2 h$ = 3.7413 x 10^{-12} watt cm^2

C_2 = hc/k = 1.4388 cm-K

e = 2.71828 NAPERIAN BASE

ϵ = EMISSIVITY FACTOR (BLACK BODY = 1)

σ = STEFAN-BOLTZMANN CONSTANT

c = VELOCITY OF LIGHT = 2.99793 x 10^{10} cm/sec
= 2.99793 x 10^{14} micron/sec

h = PLANCK'S CONSTANT = 6.6256 x 10^{-34} watt sec^2

k = BOLTZMANN'S CONSTANT = 1.38054 x 10^{-23} watt sec/K

$1/\pi$ = MEAN, NORMALIZED RADIANT FLUX PER UNIT PROJECTED SOLID ANGLE